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THE CHEMISTRY OF THE POTTERY INDUSTRY.*

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The discovery of porcelain and the beginning of its manufacture in Europe was through the labor of a chemist, Friedrich Böttger, the story of whose quest for gold for the elector, Augustus II of Saxony, and the practical results of his experiments, is an oft-told tale.

Perhaps from the profession of its discoverer as a first reason, but certainly from the spirit that it should profit by all the assistance that science could render this beautiful art, the pet of the states and princes of the last century, the porcelain factories of Europe were among the first industries, except the pharmaceutical and metallurgical ones, to benefit by the constant assistance of chemists.

The national factory of France, at Sevres, was, from its beginning to the present time, almost constantly under the

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direction of men who ranked among her ablest chemists. And yet, the pottery industries at large, although they offer many problems whose solution lies purely within the province of the chemist, have given him practically no opportunity of adapting his researches to assist in lightening the difficulties that beset them. And it is only within very recent years that chemists themselves, who had rendered such signal service in the development of the most difficult and aristocratic of ceramic products, porcelain, felt tempted to extend their interest seriously and extensively to the more common but far more important products of the industry, from purely scientific interest. Yet, not until the field of ceramic labor was so extended by chemists themselves can their efforts even on behalf of porcelain, successful as they had been in their *results* in obtaining a beautiful product and rational manufacture, be said to have borne fruit from a chemical standpoint. For after all, if you consider the labor of even the most distinguished of the older chemists who devoted themselves to this work, Brogniart and Salvétat, they only assisted empiric experiment with general chemical reasoning and with analytical control of the various raw materials that were used.

Not until a later chemist, Dr. Herman Seger, who had directed his main energies to a study of the commoner clay wares, made his classic investigation on the nature of Japanese porcelains, was something like scientific light shed on the constitution of porcelain glazes in general, their relation to the composition of bodies upon which they can be melted without defect, and their chemical formulæ in relation to the general chemical formulæ of pottery glazes.

I take it that an important reason why chemists have had little opportunity to make themselves useful in the field of pottery manufacture, lay in the fact that the acquirements of one who would render service must lie in so many directions, and be coupled with so much practical experience relative to the physical and mechanical treatment of materials, that a knowledge of chemistry, without a practical apprenticeship in the craft, seemed a rather insignificant weapon with which to attack difficulties that are often like

the hydra, hundred-headed, and in which the chemical side is but a single factor. And this was particularly the case before something like a scientific groundwork had been laid of the constitution of pottery glazes.

Furthermore, experiences which have been made under the anxious strain of great commercial risks, as those of the potter very commonly are, in his having to submit to the uncertain element of fire, large quantities of ware upon which he has spent much labor, made in mixtures that are tentative, of materials uncertain in composition, and that to a single burning which, like the cast of a die, may win or lose, make a man timid, doubtful and secretive about the method of his results. And if the results of years of anxious experiment are reducible to the knowledge of a few particular materials and a few formulæ for mixing them, to the several components and colors of his ware, which he can record on a little slip of paper and carry in his vest-pocket, while he carries the standard for the measure of the fire, for perfecting them, in his eye, it is but natural that the maker of experiences which come down to such an absurd compass, and yet are so momentous to him, will have an exaggerated opinion of the value of receipts and of particular results instead of general methods. As he looks back upon the chaos of haphazard trials that have led him to his final results, he cannot believe that such experiments can be reduced to an orderly system. And he generally does not wish to know that such a system will accomplish, in a few hours of calculation and a few weeks of experiment, all that he required years to achieve. It would seem a mockery to his intelligence and a belittling of his most serious efforts. Fancy the wrath and contempt of Christopher Columbus, translated to this century, for a Cook's tourist who had made his tenth summer vacation trip to Europe!

Hence, I take it that the very risks and difficulties of the potter's craft gave its members so conservative, suspicious and secretive a temperament, that they were not willing to lay their experiences before a professional adviser, with the unreserved freedom that is essential to all theoretic service, whether it be a client disclosing his business transactions

to his attorney, a patient detailing his symptoms and habits to the physician, or a manufacturer laying his methods, his experiences and aims before the chemist or engineer. And so it is a curious chapter in human limitation, that while *chemists* solved the problem of making *porcelain*, though the skilled potters of Delft and of all Europe had failed, these, nevertheless, held aloof from seeking the service of the men who accomplished the most difficult feat in their own craft.

The pottery industries, instead of being among the first to find a field for the chemical engineer, as they logically should have been, are among the last. In Germany and France it is probably not twenty-five years since potters have thought of such a thing; in England and with us, it is not seriously considered yet.

After the passage of that celebrated English law, later copied in this country, which compelled manufactures of foreign make to be stamped with the name of the country of their production, England awoke to an astonished realization that the best of the wares she had approvingly fancied came from her celebrated Staffordshire district were "made in Germany"—by a country poorer in clays and fuel, whose labor and products she had always been content to look down upon as being what Professor Reulleaux had once stigmatized them with being, *billig und schlecht*—cheap and bad.

The reason of Germany's rapid and successful industrial development is well known, and it should be a source of hopeful satisfaction with us in America that while most of our industries have grown on English models, we are not so stereotyped in their adoption but that we are able to improve them by the aid of applied science and art from without the trammels of the particular craft, which England seems much less able to do. Our pottery industries are, perhaps, more distinctly English than any other. Our ware, our methods, the majority of our pottery workmen, are English.

The enterprise, diligent persistence and skill in empiric experiment which are characteristic of English industry, and have brought her pottery work to reputable perfection

and given some of the achievements high celebrity in ceramics (Wedgwood, Royal Worcester, Crown Derby, etc.), are qualities that have not left the men who brought the art to this country and have raised it to great commercial importance.

The time is now ripe for the application of scientific methods to its processes, as empiric ones can scarcely accomplish more than the results of our English prototypes, which we have already reached. Competition from our Continental rivals, with whom more scientific methods obtain, besets us. Artificial political barriers are foolhardy and a wrong, if they undermine the energy that prompts men to seize and learn all instruments for perfecting their craft.

The Franklin Institute, which has labored so long and so successfully in the cause of applying science to our industries, will, I am very sure, find it a grateful task to stimulate its aims in a field of great industrial importance that is, as yet, quite new.

Let me remind you what the material entering into the making of pottery is, and call your attention to the more common problems and difficulties that beset the potter. It will then be possible to give a brief survey of the resources that chemical methods and reasoning open for the solution of the technical questions that arise with him.

All ceramic products are, of course, fashioned from clay and are hardened to permanent form by baking or burning. But no raw material varies so widely in composition and physical properties as do the clays, and the products of no other material are put to uses as widely divergent, calling forth all the characteristics of its different kinds and those developed by the different treatment and degree and quality of burning to which they may be subjected.

Unlike every other mineral, it is never a question—is it rich enough or pure enough for the one or two objects of its utility? You may say, *a priori*, every clay has properties that make it of particular value for manufacturing some article of use. But the very wealth of its industrial application, and the variety of qualities which it can be made to exhibit and are the condition of its extensive and varied

use, have so overwhelmed men that they abandon hopelessly almost every attempt at an orderly and systematic investigation of the qualities which a particular clay deposit has, and pitch upon a use for it in the most haphazard way; or in selecting a clay for some particular use, go at the work in the blindest empiricism.

You can best appreciate this by investigating the commercial history of the clay industries. I think you will find that most factories have passed through one or two crises; that many are producing some other product than the one they were originally built for; that nearly all of them have paid so dearly for their technical experience; that their capitalization is higher than it should be, and that the cost of production is affected by the evil of having to perpetuate the consequences of a situation irrationally chosen and a factory system based upon the manipulation and burning of a material that had afterward to be abandoned without being able to abandon the machinery and kilns adopted for it. Thus much for the difficulties that the very abundance and variety of *the* pottery material par excellence raises; and if the difficulty of selecting the right kind, determining its proper mode of working and the kiln and temperature for burning it for a definite purpose, is already great, it will occur to you that these considerations are largely complicated, when, as in most cases, the clay is to be incrustated with other clays and glazes, and decorated, perhaps, with colors and enamels. Questions of shrinkage, of coefficient of expansion, chemical action and solution by the fusing glasses, come into play.

In the modern ornamental building brick and the vitrified ones, fast becoming our most important paving material, ordinary floor tile and drainage pipes, you have but the first considerations. But in all that you commonly think of, when one speaks of pottery, the thousand and one *containers*, of domestic, ornamental and industrial use, from the acid still and pump of the chemical factory to the soup tureen, the Dresden clock case or the Crown Derby vase, you have a clay form or body, covered with a glass or glaze, and often a decoration in color over or under the latter.

The following are some of the problems which the potter must solve: Architects require the ornamental terra-cottas and friezes upon buildings in great varieties of color. The clays which would produce them are, in the majority of cases, too expensive or often absolutely impractical for forming and burning the heavy pieces required. It, therefore, becomes necessary to make the body of the terra-cotta of a clay or mixture of clays that will have the necessary physical qualities, and prepare a series of encrusting clay mixtures that will adhere to it without defect, and produce, under the fire at which it must be burned, all the required tints.

All clays shrink considerably, both in drying and burning, and the shrinkage of clays differs materially not only in the aggregate, but in the different stages of drying and burning. If, therefore, the movements of the encrusting clay are not absolutely in unison with those of the body upon which they are placed, the former will shell off entirely or in parts. As the error does not always show itself at once, and as after the fire it is irremediable, and with it the entire product is lost, the problem is difficult in its subtlety and serious in its miscarriage.

The glaze covering on pottery is very difficult to obtain empirically. It must be a perfect glass in transparence and brilliance. But a *glass*, no matter how beautiful, cannot be melted upon pottery without devitrifying and entirely losing its characteristic qualities. The potter has, therefore, built up his glaze by himself without assistance from the glass-maker, and believes a *glaze* radically different from a *glass*.

But even with transparence and brilliance attained, the problems attaching to the making of the glaze are but begun.

In order to fulfil its principal mission of yielding an impervious coating to the clay body of the ware, which, even in the case of translucent and vitrified porcelain, is not absolutely impervious to the penetration of liquids, it must not crackle through use. In other words, it must undergo the same movements of expansion and contraction as the body upon which it is fused. These movements of a piece of

pottery under the fluctuations of temperature are very slight, it is true, but they are very positive, and transcend the limits of elasticity of both the glaze and the clay body, unless these are very closely adapted to each other in their coefficients of expansion, because of the intimacy with which they are attached to each other.

If the coefficient of expansion of the glaze exceeds that of the body and its movement goes beyond the elastic limit of the latter, the glaze will push off at the edges of the pieces of ware, tearing the clay off with it. And in case the disagreement is great, it will pull off the handles and spouts of the piece, or even shiver the whole to a mass of splinters.

Where the coefficient of expansion of the body is the greater, exceeding in its movement the elastic limit of the glaze, this cracks, and the fineness of mesh of the intersecting lines of fracture is directly in proportion to the degree in which the two are at fault.

This difficulty never occurs with glass itself, for it is due to the interdependence of the two bodies constituting the pottery piece.

It will, therefore, be clear to you that the composition of the clay upon which the glaze is to be used must itself be experimented with and modified to meet what cannot be accomplished by the glaze alone.

When these problems have been solved and a glaze and body perfectly co-ordinated, the decoration of the ware, by printing or painting with ceramic colors, may prove the glaze entirely unsuited to such treatment, and the labor of perfecting it and adapting it and the body to each other entirely in vain.

You will remember that after a piece of ware is fashioned it is commonly fixed to permanence by burning, before the glaze is applied. This first fire, which hardens the clay, is known as the "biscuit fire," and upon the "biscuit" or baked but unglazed ware, decorations which are desired of absolute durability, as in the case of dishes, or of particular brilliance, as in the finer faïences, are applied by printing and hand-painting in ceramic colors. Then the glaze,

ground to creamy consistence in water, is washed over the whole piece, and in a final glost fire it is melted to a transparent varnish, covering and absolutely protecting the decorations between it and the body.

The colors that are used must, in order to resist the high temperature requisite, consist of metallic salts and oxides, and these are all more or less soluble in melting glass fluxes. These colors must, therefore, be mixed so as to resist solution in the glaze that is to be fused over them as much as possible, and this must be of a character that its solvent action in fusing is small, for in this property glass fluxes vary widely. A glaze, perfect in every other respect, which eats off in melting these "underglaze" colors, as they are called, would be utterly useless for ware decorated in this manner.

Again, where glazed wares are to be gilded or decorated in easily fusible enamels and vitrifiable colors upon the glaze, decorations even more extensively practised, the glaze must stand repeated fires, at a temperature lower than its melting point, in which these are fused and fixed without suffering devitrification.

The composition of glass fluxes profoundly affects the tints produced in them by chromogenic oxides, and pottery decorated with colored glazes must be adapted to bearing a variety of these, though all must conform to the fundamental requirements of a uniform coefficient of expansion and being perfect glasses.

The first service that the chemist must render to supply data for the solution of these common problems and difficulties that beset the potter, and which I have enumerated, consists in classifying, or at least describing with positive factors, physical as well as chemical, the host of clays that geological, mining and engineering work are constantly disclosing and that the public is anxious to put to industrial use.

It is to be regretted, but it is, nevertheless, the case, that almost all the labor which chemists have spent upon countless clay analyses for geological surveys, whether at public or private expense, has been practically thrown away, for

the reason that none of them go far enough, and are accompanied with the necessary physical tests and descriptions to classify them, and give the practical worker a mental picture of what they will do under his kiln-heats and under his glaze.

In the first place, an elementary analysis of a clay, which is practically the only kind made, tells the potter little or nothing. Suppose you had a vinegar or a sugar syrup which you wanted analyzed, and the chemist to whom you took it should make a combustion of each and inform you how much carbon and oxygen and nitrogen and hydrogen they contained, what would you do? You would laugh at him.

You want to know how much acid the vinegar contains, and if some of the acid be malic acid, so that you can tell whether it was made from apple cider or not. You want to know, in the case of the syrup, how much saccharine matter it contains, and how much of it is cane sugar and how much glucose. Now all of these substances contain the same elements, carbon, hydrogen and oxygen, but they are grouped into compounds of very different properties, and the proportions of *these* are what you are anxious to know, because these and their amounts determine the value of the vinegar or the syrup.

Now let me explain the business of a chemist to you. He works largely by analysis; that is, by picking things apart, so that you will understand the character of a compound from its components. But there are two kinds of compounds, those which are mixtures and those which are homogeneous chemical bodies. The vinegar I spoke of is an example of the former, the acetic and malic acids it contains are examples of the latter. To pick apart the *mixture vinegar* so you will understand it, you separate the chemical compounds that compose it; to analyze the acetic acid, which is a homogeneous chemical compound, so that it may be understood, it must be resolved into its elements, carbon, hydrogen and oxygen, $\text{CH}_3 \cdot \text{COOH}$. If the chemist resolves the mixture at once into its elements, he goes too far and tells you practically nothing.

It would be like the anatomist who wished to show you

the structure of a chicken, and who, instead of removing the feathers to disclose the naked body, and the skin to display the muscles, and finally removed these to show the viscera and the osseous structure, put his bird into the meat chopper and reduced it to a pulp! His dissection would be so thorough that you could make neither head nor tail of it. Now this is just what chemists, out of touch with the pottery craft, have been doing. Instead of resolving unknown clays for the potter into the skeleton, the plastic muscle and the binding skin, they have put them into the analytical meat chopper and turned out elementary pulp!

Look at any geological or mineralogical book for the composition of a clay, and you will find some such answer as this:

	Per Cent.
Silica	50.02
Alumina	35.18
Oxide of iron	0.36
Lime	0.12
Magnesia	0.07
Alkalies	3.39
Combined water	10.57

And what does all this maze of elements mean? That this natural clay consists of

- 84 per cent. of true clay substance—the *plastic element*—the muscle.
- 9 per cent. of fusible mineral, feldspar—the *binding tissue*—which melts on baking and bonds the particles together.
- 7 per cent. of quartz or flint—the *skeleton*.

Now, you have the unknown clay resolved into its proportions of the three simple components of its structure, and the potter can tell you at a glance that *that* clay will not make a pottery body by itself. The skeleton is far too weak and the binding tissue insufficient; but he can now readily see how much flint and feldspar he must mix with his clay to answer for making his pottery body, and so he is saved much anxious work and tedious experiment by this solution of the chemist. But why has not the chemist answered thus simply and directly long ago? The simple analysis is hard to make, the simple answer the most difficult to find.

The glaze is a far more perplexing material to the potter

than the body, and I have enumerated a few of the difficulties that are encountered with it. It is made of a variety of materials that are difficult to survey, and, though the potter mixes these himself, from the fact that they lose their identity in fusion, it is difficult for him to foresee what the increase or diminution of one or the other will effect in the glaze. These are the constituents of common glazes: potash, soda ash, white lead, zinc oxide, borax, boracic acid, feldspar, Cornish stone, chalk, clay, quartz or flint. A porcelain glaze usually consists only of feldspar, chalk, clay and flint. Complex and different as these bodies are, you have, when they are melted together into a glaze, a homogeneous chemical compound.

In order that this may be surveyed and changed positively and at will to meet the different needs which I have indicated to you, the chemist must render the same service in reasoning about the glaze as he has about the clay and pottery body, namely, reduce it to the few simple elements of its actual structure. But, as the melted glaze is a homogeneous chemical body, like the acetic acid in the vinegar, it will be necessary to go into the chemical elements. Let us examine the very different materials I have enumerated for you as composing glazes—what do they consist of chemically, in all that would remain of them in melting?

The oxides of metals, as in the potash, soda ash, white lead, oxide of zinc, chalk—these the chemist calls “bases.” Now, the quartz and the boracic acid are both acids and the borax, feldspar and Cornwall stone contain both bases, that is, oxides of metals and one or the other acid, and, finally, the clay, besides containing an acid—silica—contains the oxide of a metal—alumina—which does not exactly behave like the others, namely, as a base, but seems to occupy an intermediary position between a base and an acid. It is again a connecting link between these two, so the complicated glazes also consist of only three units, though these are composed of chemical *elements*,* as the body or the clay consists of three, though these are chemical *compounds*.

* It goes without saying that this term is not used in its strict chemical sense.

The scientific chemist will take some exception to these trilogies, but they are none the less useful for a practical comprehension of the facts.

Now, let me divide two glazes for you, and show you the application of such a chemical division:

	<i>A</i>	<i>B</i>
Borax	24	48
Chalk	25	12½
White lead	33	65
Feldspar	23	
China clay	23	26
Boracic acid	15½	
Quartz	57	63

Here are two glaze receipts. I question whether any potter would venture an opinion if either would give a perfect glass or not on melting, and if so, what the properties of each would be. It is practically impossible to do so, on account of the number and the mixed character of the constituents. But upon resolving them into their chemical divisions and elements, they are easily compared, and the phenomena of their behavior explained even by the potter untrained in chemistry. If he have the glaze mixtures which he uses in his work, and the experimental mixtures which he prepares, constantly reduced for him by a chemist into the fundamental chemical groups that compose them, the empiric receipts which can never be surveyed are resolved into intelligible factors, and a little practice in studying these, in conjunction with the phenomena that the glazes exhibit after coming from the fire, will soon enable him to experiment with a certainty in the direction that his aims dictate, which, without this help, is at the mercy of the blindest chance.

In order to make this reduction of empiric glaze mixtures into simple chemical formulæ, I prefer to do so by making use of the old "combining weights," which unite the combination of the elements by their atomic weights and by valence into one expression, reducing the sum of the "combining weights" of the bases to unity, or, perhaps better, to 10, avoiding fractions and chemical symbols as much as possible, so as not to confuse the practical potter.

The receipts given reduce to the following chemical formulæ :

<i>A</i>		
2·5 Potash and soda.	} 3· Alumina.	30· Silica (flint).
5·0 Lime.		5· Boracic acid.
2·5 Lead oxide.		
<hr/> 10·0 Bases.	3· Intermediary elements.	<hr/> 35· Acids.

<i>B</i>		
2·5 Potash and soda.	} 2· Alumina.	25· Silica (flint).
2·5 Lime.		5· Boracic acid.
5·0 Lead oxide.		
<hr/> 10·0 Bases.	2· Intermediary elements.	<hr/> 30· Acids.

The potter will find that mixtures varying widely from these in the proportions of their principal groups will not produce glazes under the conditions of the pottery glost fire, and he can spare himself the trouble of trying them.

A glaze that is high in silica is less likely to craze, but more in danger of shivering, so that *A* may shatter a body made of a siliceous clay mixture, upon which *B* stands perfectly. But the latter may craze upon a biscuit proportioned to carry *A*.

When the bases are rich in heavy metals, particularly in lead, and the acids in boracic acid, the resulting glaze has a high refracting index; glaze *B* is, therefore, more brilliant than glaze *A*. But lead glasses have a more yellowish cast than lime glasses, so that *A* is the whiter of the two.

The same factors that increase the brilliance of a glaze, a larger proportion of heavy metal oxides in the bases and boracic acid in the acids, lower the fusing point.

A proportionate increase of boracic acid and lowering of alumina increases the solvent action of the glass for chromogenic oxides. *A* attacks underglaze colors less than *B*, but the latter is the better basis for ornamental colored glazes.

The many phenomena exhibited by pottery glazes can be followed and understood by comparison with their chemical formulæ, but the examples already cited will suffice to show the assistance that a chemical division of their constituents can render in judging them. The same is equally true of the ceramic colors, with which the potter has to deal.

Perhaps the most mysterious of the seats of the potter's trials lie in the fire. This is the proof to which all his ware must be put, and here is the cause of his most perplexing failures. But this element, too, has been resolved by the chemist into its simpler phases, and the measurement of the higher temperatures by simple and accurate means, and the analysis of the flame by simple apparatus that can be put into the hands of any fireman, are accomplished facts, concerning which the potter can get full instruction from the chemist. It would, perhaps, lead us too far to discuss the chemical effects of the quality of the fire upon pottery colors, but I can illustrate its far-reaching results by two pieces of ware that I have here for the purpose, a piece of celadon and one of red Japanese porcelain.

The chemical formula of these two glazes is exactly the same; it is:

3' Potash.	}	5' Alumina.	{	40' Flint (or silica).
7' Lime.				
Trace copper oxide.				
10' Bases.	5' Intermediary.	40' Acid.		

The only difference in their treatment is that in the glaze fire this green piece was in a flame containing a little more air; it was in what chemists call an oxidizing fire, this red piece was in a reducing fire.

The difference in quality of flame was very subtle, but the result was radical and momentous. Perhaps the money value that the connoisseur would put upon them will tell this better—the red piece is of the order of the celebrated Japanese and Chinese red porcelains, known according to their tints as “ox blood,” or “chicken blood,” “*sang de boeuf*,” or “*sang de poulet*.” If the flame had been so perfect that the entire piece had been red, without the white portions, it would be worth several thousand dollars; as it is, it is only worth as many hundred, while the green piece is but worth as many hundred cents.

It is the business of science to disclose practical facts that lie a little under the surface and removed from the observation of ordinary men. It is necessary often to coin new names for these facts, and these sound very perplexing

while they are unfamiliar. But the facts of science and its terminology rapidly become common property of the masses, when there is use for them. You hear street-car motormen and telephone linemen talk of watts, and ohms, and ampères, and fields, and commutators, words only used by a professor of physics ten years ago.

Samuel Pepys tells us that in his time the multiplication table was a notable scientific discovery, and fellows at Cambridge University and men of scientific attainments studied it. We may smile at the simplicity of our ancestors, but it is likely that posterity will smile at us, for the chemistry of many of our common avocations is at bottom as simple and as necessary as the multiplication table in the market and the counting-house.

The multiplication table not only tells us what we can do, but what we cannot do—that we can get ten dimes, but that we cannot get five quarters, for a dollar.

So also, the greatest value of science applied to an industry consists in giving a survey of the attainable ground and the means of knowing what is beyond the possibility of achievement.

The empiric experimenter is an optimist, and believes that he can accomplish much which is simply unattainable. He, therefore, loses much valuable time in futile effort. He is like a fly that butts its head against a pane of glass, never realizing that transparent media may be impassable.

If, therefore, I have led any potter here this evening to hope that with chemical aid he may attain some object he has striven for in vain, in his body, his glaze, or his fire, I must warn him also that the answer he *may* get is that he has been on a fool's errand in his quest. I have tried to show you that in this age of industrial science we have an important craft, that in progressive England and America is still plodding along without scientific aid, although chemistry picked up the most difficult of its branches a century and more ago and brought it to perfection, when the cleverest potters of Europe could not do what it accomplished, namely, the making of porcelain.

I have tried to show you why the very difficulties of pot-

ting deterred the potter from calling the chemist to his aid, even after this demonstration of his abilities, but that the chemist was also in large measure responsible for this estrangement, in that he piled up analyses upon analyses for the clay-worker's benefit, but without a knowledge of his needs and, therefore, in forms in which he could not use them.

This period is passed. The chemist has penetrated the mysteries of this black art also, and, as I have tried briefly to sketch, can lay bare the practical conditions that underlie the problems of the potter and aid him greatly in his work.

SANITARY PROBLEMS CONNECTED WITH MUNICIPAL WATER SUPPLY.*

BY PROF. W. P. MASON,
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This subject is in some danger of being over-written to-day; but we have about us material evidences that it is not over-studied, especially by those boards of public officials whose responsibilities are often much greater than their knowledge of sanitary principles.

Everybody seems to be talking or writing about water, but the public is very far from being well posted upon the subject, and one encounters all sorts of odd views, which are remarkable not only for their character, but also for the tenacity with which they are held.

Ocular evidence of purity is quite sufficient for most people. The bright and limpid water from a well which drains a graveyard is counted a blessing by those who would shudder at the thought of a cholera ship touching at one of our most distant ports. Nor is faith in the self-purifying power of running streams any less pronounced. The writer had the following curious criticism made of his report condemning the use of a sewage-laden river water:

"We would hint to Prof. Mason^{*} that every impurity

* A lecture delivered before the Franklin Institute, March 19, 1897.